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Bureau of Solid Waste Management

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SOLID WASTE DISPOSAL

IN YELLOWSTONE NATIONAL PARK

A Division of Technical Operations
Open-File Report (TO 1.1.101/0)

written by Harry R. Little, Engineer

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Solid Waste Management
1970

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SUMMARY

A brief summary of present solid waste practices in Yellowstone National Park follows:

Administration

Solid waste management is the responsibility of the Maintenance Division of Yellowstone National Park. The Park is divided into three districts, each having a maintenance supervisor. Records are kept on the amounts of waste collected and these are reported in terms of the equivalent number of 32-gal containers collected.

Storage

Three types of containers are generally used for solid waste storage in the Park. These are 20-gal galvanized containers at residences, 32-gal galvanized containers at hotels and restaurants, and 32-gal galvanized containers that have been modified so as to be bear-proof at outdoor locations. Plastic liners are used in all containers at a cost to the Park Service of about $2,500 annually.

Collection

The Park Service operates seven 13-cu yd packer trucks, four ½-ton pickup trucks, and three 1½-ton stake body trucks for solid waste collection. A total of 35 men are used for collection during the height of the visitor season. The annual cost of

solid waste collection is estimated at $128,300. For the estimated 5,700 tons of waste collected annually, this is about $23 per ton.

Treatment and Disposal

Three incinerators and two open dumps are being used by the Park Service for solid waste treatment and disposal. The total estimated cost of solid waste treatment and disposal at Yellowstone National Park is $72,900 per year, or $13 per ton.

Mammoth Incinerator. This incinerator processes 1,600 tons of waste per year at an annual cost of $32,600, or $20 per ton.

Lake Incinerator. An annual cost of $21,600 is necessary to incinerate 1,200 tons of waste yearly at this plant, for a cost of $18 per ton.

Grant Village Incinerator. The incineration of 800 tons of waste each year results in an annual cost of $15,200, or $19 per ton, for this incinerator.

Trout Creek Dump. An operational expenditure of only $300 per year gives this dump the lowest disposal cost in the Park. With 800 tons of waste deposited annually. the cost is less than $1 per ton. The placement of waste in the groundwater at this site presents a serious problem requiring immediate solution.

Rabbit Creek Dump. The presence of geysers and hot springs near this site make operation difficult, even though a tracked front-end loader is used to cover the waste every other day. The cost of this operation is $3,200 per year, or $3 per ton for the 1,200 tons of waste dumped here annually.

The incinerators in the Park are not acceptable either in terms of waste disposal or operator safety. It is doubtful if these incinerators can meet existing Federal regulations governing air pollutants. The two dumps are unsanitary, unsightly, and also in violation of present Federal standards.

TABLE I

ESTIMATED ANNUAL COST OF SOLID WASTE MANAGEMENT, YELLOWSTONE NATIONAL PARK

Type of Cost	Amount ($)
Administration	Not Available
Storage*	2,500
Collection	128,300
Disposal	72,900
Total	203,700

*Includes only the cost of plastic liners.

RECOMMENDATIONS

The National Park Service must make definite commitments to solid waste management in Yellowstone National Park if they are to maintain a natural and pleasing environment and protect the ecological balance of the Park. In order to achieve the goals of improved waste management, the following recommendations are made.

1. The system of record keeping and reporting should be retained and improved. Records should be kept on all collection crews and all disposal sites. Examples of the types of forms that can be used are available from the Bureau of Solid Waste Management, Cincinnati, Ohio.
2. The two open dumps now in existence should be closed and replaced by sanitary landfills. These landfills can either be operated at the same locations, or moved to better sites in the area.
3. More attention should be given to residue disposal at the three incinerators. All organic material is usually not destroyed by burning and the residue will require sanitary landfill type disposal.
4. Consideration should be given to abandonment of the incinerators at the earliest possible date.
5. When the incinerators are closed, additional sanitary landfills should be established.

6. Investigations should also be made on the establishment of a central disposal facility (either an incinerator or a sanitary landfill) and the effect that this would have on the collection system.

7. The possibility of a disposal facility operated in cooperation with the U. S. Department of Agriculture, Forest Service, Gallatin County, Montana, and the community of West Yellowstone, Montana should be investigated.

SOLID WASTE DISPOSAL
IN YELLOWSTONE NATIONAL PARK

Yellowstone National Park was established on March 1, 1872, and is the oldest unit in the National Park System. It contains about 3,400 sq miles and is located in the northwest corner of Wyoming with areas extending into Montana on the north and west and Idaho on the west and south (Figure 1). The Park was established to provide present and future visitors with the opportunity to see and appreciate the natural scenery and native plant and animal life as it occurred in primitive America.

Each year millions of people visit Yellowstone National Park to enjoy the area's unique geologic formations and to view the abundant wildlife. In the first 9 months of 1969 more than two million people visited the Park (Table II). To accommodate this large number of visitors, hotel and cabin units have been provided, campgrounds have been constructed, picnic and visitor areas have been built, and miles of roads, trails and walkways have been furnished. All of these visitors have one common feature which is independent of where they are from, where they are going, or how long they stay in the Park. This is the common characteristic of waste production.

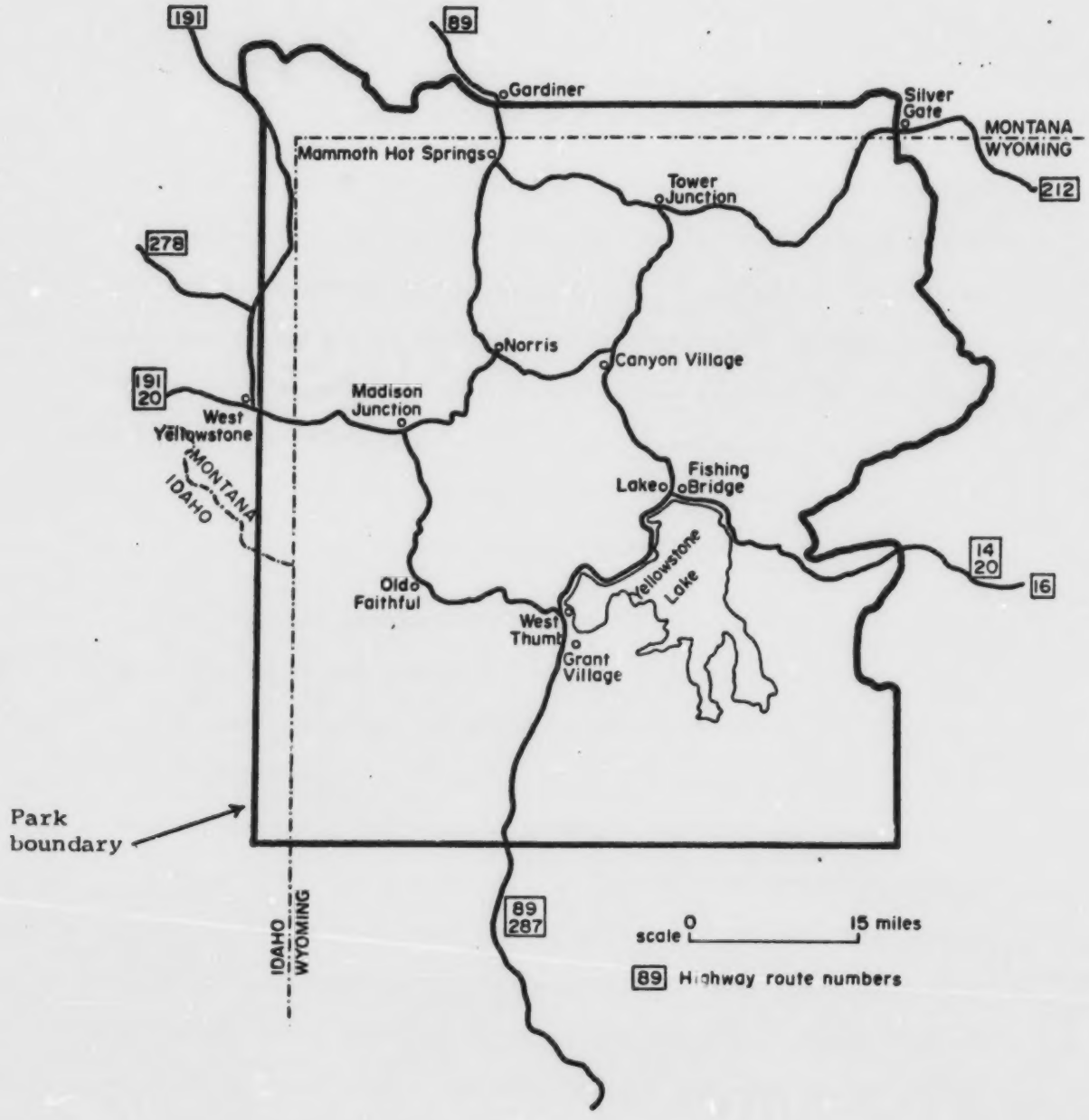

Figure 1. Yellowstone National Park.

TABLE II

NUMBER OF VISITORS TO YELLOWSTONE
NATIONAL PARK - 1969

Month	Number of Visitors
January	3,589
February	5,056
March	5,613
April	8,999
May	100,722
June	384,592
July	733,955
August	688,553
September	223,232
October	45,000 (est.)
November	3,500 (est.)
December	3,500 (est.)
Total	2,206,000 (est.)

To handle these wastes, both liquid and solid, the Park Service must maintain and staff treatment and disposal facilities and employ people to collect the solid waste. This represents a major investment in equipment and personnel, but the Park Service cannot afford to do less than the best job possible. The mission of the Park Service is to maintain a natural environment, and they must be most careful to avoid any situation that would change the delicate balance of nature.

A situation has arisen in the Park, however, that threatens to alter the natural ecosystem (Figure 2). This is the habit developed by large numbers of bears and other scavening animals of feeding at dumps. The grizzly bears, however, present the major problem (Appendix A). Bears that feed at dumps overcome their usual wariness toward the sight or odor of humans. The dumps tend to concentrate large populations of bears in small areas, and it is only a matter of time before some bears are cha ed off by the larger group members. These displaced bears often move into campgrounds and other developed areas and are a potential danger to visitors.

If the dumps were closed, it appears likely that the bears would disperse throughout the Park and once again become dependent on natural food sources. The re-establishment of the grizzly bear in the food chain would seem desirable to preserve both the integrity of the species as a wild animal and the validity of the Park as a natural area.

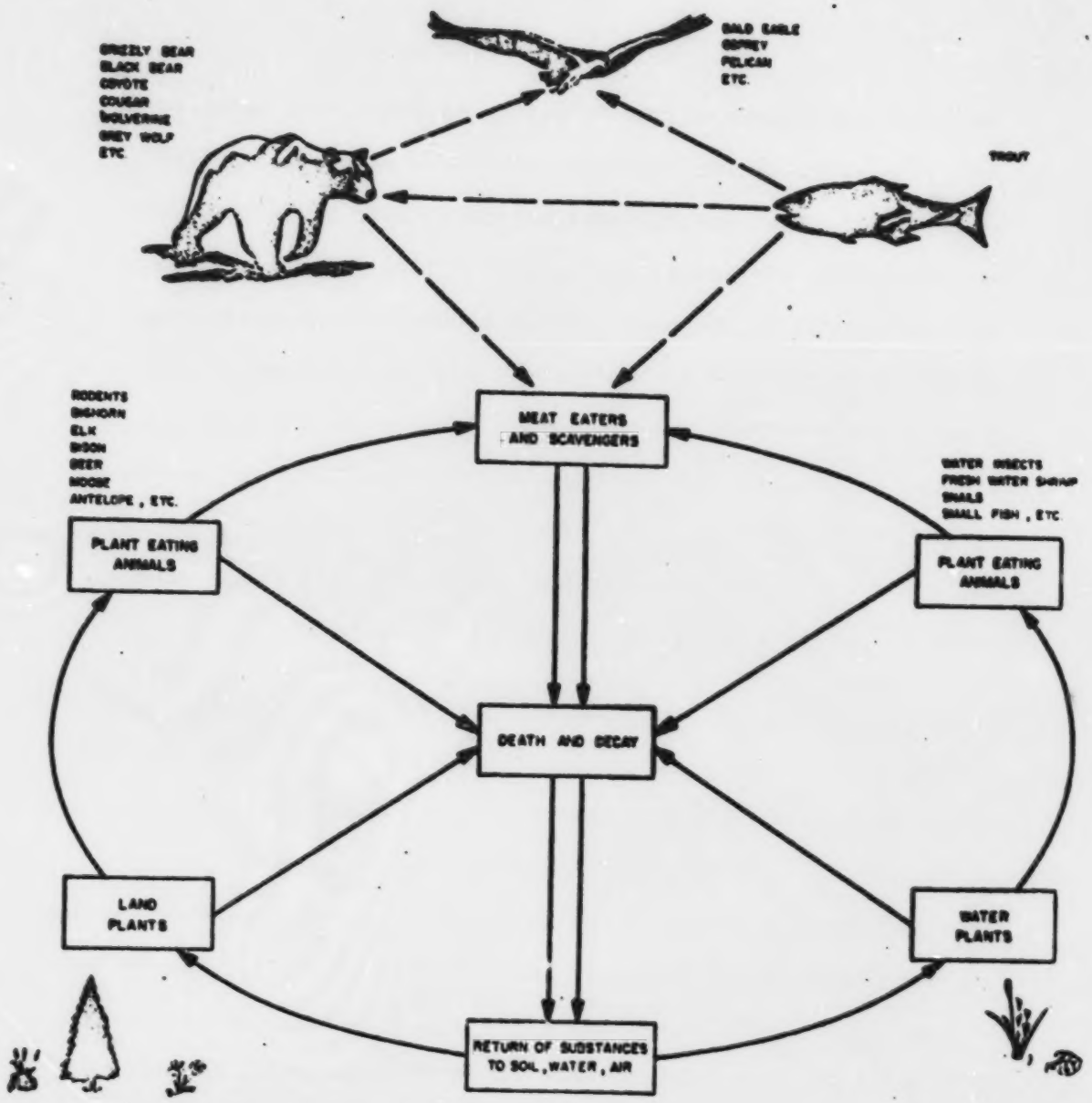

Figure 2. Ecosystem in Yellowstone National Park.

Source: U. S. National Park Service, Yellowstone National Park

The U. S. Department of the Interior, National Park Service, has long been aware of the problems associated with the improper storage, handling, and disposal of solid waste at Yellowstone National Park. In addition to the resulting pollution of air, land, and water by the waste, large numbers of bears and other animals are attracted to areas where they have access to the waste. These animals concentrate in areas that are heavily visited by tourists and the bears can be a major threat to the safety of the visitors. The ready supply of garbage and other solid waste can also remove these bears from the natural food chain and thereby alter the ecosystem of the Park.

The Park Service has spent a great deal of money in Yellowstone to keep bears out of solid waste storage containers, but little attention has been paid to the problems of improperly operated disposal sites. Incineration is practiced in an effort to destroy the organic matter in the waste and to reduce the total volume of waste, but the incinerators are often overloaded and do not burn off all of the organic matter. A large portion of the solid waste goes directly to open dumps where it is left uncovered and has become a major attraction for bears and other animals.

In September 1969, Yellowstone National Park officials requested assistance from the Bureau of Solid Waste Management in helping them improve their solid waste disposal practices. The request to the Bureau was referred to the Division of Technical Operations through Mr. Bert W. Mitchell, National Park Service Consultant, Environmental Control Administration, Denver, and Mr. John T. Talty, Solid Waste Management Representative, Environmental Control Administration, Denver. Mr. Harry R. Little, Staff Engineer, Technical Assistance and Investigations Branch, Division of Technical Operations, went to Yellowstone National Park for the period of October 13 to 17, 1969. This report contains the information and recommendations that resulted from that visit.

The recommendations contained in this report are made specifically for Yellowstone National Park, and are made in light of their unique problems. Solutions other than those advanced might be more applicable to other areas having different problems.

PRESENT SOLID WASTE MANAGEMENT PRACTICES

The management of solid waste involves coordinating the needs of all the parts of the solid waste system. This includes storage, collection, treatment, disposal, and the equipment and personnel necessary to fulfill all of these obligations. In order to place subsequent discussions of treatment and disposal in their proper perspective, brief mention will be made of present administrative, storage, and collection practices.

Administration

Solid waste collection and disposal in the Park is the responsibility of the three district maintenance supervisors. They have direct control over personnel in their respective districts and are also charged with road repairs, general campground maintenance, and similar responsibilities. The district maintenance supervisors report to the Park Maintenance Supervisor, who works under the direction of the Chief of Maintenance. All maintenance operations are among the responsibilities of the Assistant Superintendent, Operations, who reports directly to the Park Superintendent.

To aid in the administration of solid waste activities, several forms are routinely used for reporting and record keeping purposes.

Among these is a daily work form that is completed by collection truck drivers (Figure 3). This form is only used for non-government operated facilities and is primarily designed so that concessionaires can be charged for the amounts of waste collected. District maintenance supervisors compile the daily reports from the drivers and monthly estimates of the solid waste collected from all areas in their districts (Figure 4). A monthly report is also submitted on incinerator operating costs and the amounts of waste received at the incinerators (Figure 5).

As can be seen on the aforementioned forms, an accounting system for the amounts of waste collected has been developed by the Park Service using the 32-gal storage container as the reporting unit. The assumptions inherent in this system follow:

6 standard cans = 1 cu yd,

1 standard can = 40 lb.

The waste in a standard can, as would be in a camping or picnic area, would therefore have an assumed density of 240 lb per cu yd. In light of the type of storage containers used in the Park, in which almost no compaction can occur, this density is probably too high. A more realistic figure would be about 150 lb per cu yd, or:

1 standard can = 25 lb.

REFUSE DISPOSAL RECORD

National Park Service
Yellowstone National Park

Original for N. P. S.--Copy for Park Operator

Location

Date_____

Park Operator to be Charged_____

DATE	CANS	HALF TRUCK LOADS	FULL LOADS	TRUCK DRIVER'S SIGNATURE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
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29				
30				
31				

OPERATOR'S SIGNATURE

Figure 3. Collector's daily report.

YELL 223

GARBAGE COLLECTION AND DISPOSAL

For Month of_____

LOCATION	CONCESSIONER (List by Name) or GOVERNMENT COLLECTION	CANS	HALF LOAD	FULL LOAD

YELL-226

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Yellowstone National Park, Wyoming, 83020

Memorandum Date:

To: Chief Park Engineer

From: North District Maintenance Supervisor

Subject: Operating Cost - Mammoth Incinerator

Following are the operating costs from
, inclusive:

Personal Services	_____
Equipment Rental	_____
Equipment Depreciation	_____
Fuel	_____
Supplies	_____
TOTAL	_____

Total Cans	_____
Cost Per Can	_____
Total Man Hours	_____

W. E. Hape
North District Maintenance Supervisor

Figure 5. Supervisor's monthly incinerator report.

Concessionaires are charged for collection service on the basis of the total number of cans collected. Therefore, they manually pack their cans as full as possible. This results in cans from concessionaires having different weights than cans from campgrounds. This fact is accounted for by the Park Service by assuming,

15 compacted cans = 1 cu yd.

Compacted cans can be seen to have an assumed density of 2.5 times the density of standard cans. Under the present reporting system this would be 600 lb per cu yd. Again, a more realistic figure would be 2.5 times 150 lb per cu yd, or 375 lb per cu yd.

Storage

Solid waste in the Park is stored awaiting collection in three basic types of containers. Predominant among these is the bear-proof container (Figures 6 and 7) used in all campgrounds, picnic areas, parking areas, and for general litter control. This container incorporates a 32-gal galvanized can mounted on a concrete platform and topped with a steel chute to receive the waste.

Hotels, lodges, and restaurants usually incorporate a special room into their facilities in which solid waste is stored in covered 32-gal, galvanized containers. These containers are moved outside before collection. Staff housing areas for Park Service personnel

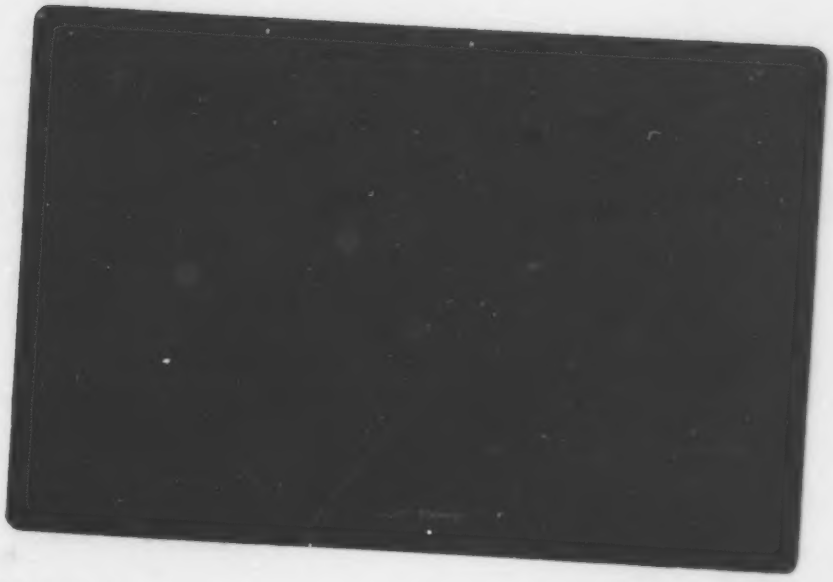

Figure 6. Bear-proof solid waste storage container.

Figure 7. Bear-proof container (rear view).

provide individual 20-gal, galvanized containers for each residence.

All types of containers are used with plastic liners at all times. This practice reduces collection time, protects the containers from the waste, and allows for less frequent cleaning and replacement. The Park Service uses about 75,000 plastic liners each year in Yellowstone at a reported annual cost of $2,500. The concessionaire in the Park, the Yellowstone Park Company, also provides plastic liners for its operations.

Collection

The number of visitors to the Park fluctuates widely throughout the year (Table II). The largest number of visitors come during a 100-day period from Memorial Day to Labor Day. The remainder of the visitor season encompasses about 80 days, from May 1 to Memorial Day and from Labor Day to November 1. All Park facilities, except in the Mammoth area, are closed from November 1 to May 1. The Park is open throughout the winter for day use only and is accessible by snow vehicles from Mammoth Hot Springs, Wyoming and West Yellowstone, Montana.

The collection equipment used during the peak season includes seven 13-cu yd packer trucks, operating 7 days per week; four

½-ton pickup trucks, operating 5 days per week; and three 1½-ton stake body trucks, operating 5 days per week. During the 80-day light season the seven packers are used 5 days per week and the four pickups are used 3 days weekly. One packer truck is used during the winter in the Mammoth area.

All collection personnel work 8 hr per day throughout the year, except for one packer crew that collects from Fishing Bridge Campground in the evening for 2 months in the summer. Three men are used with each packer truck and two men with all other vehicles.

The packer trucks are used to collect daily from hotels, lodges, and other high density areas. They are also used in campgrounds after the lodge areas are collected. Stake trucks are used along the highways to collect from campgrounds, picnic areas, and other sites between the lodge areas. The pickup trucks are used for litter control along the roads and their crews also service rest areas and toilet facilities. Stake and pickup trucks normally provide collection from once to twice each week.

The Park Service has an internal rental system for allocating the cost of equipment. For packer trucks this assigned cost (which reportedly closely approximates the actual cost) is $1.10 per hr. There is an additional monthly cost of $82.00 that covers equipment depreciation. This monthly cost must be charged 12 months a year because the packer trucks cannot be assigned to

other duties during the winter. Stake trucks cost $0.07 per mile, plus $35.00 per month. Pickup trucks cost $0.045 per mile, plus $18.00 per month. Depreciation for stake and pick-up trucks is not charged to solid waste collection during the winter because these vehicles can be used for other activities.

Average wages for packer truck drivers are $3.37 per hr (including benefits). Stake and pickup truck drivers receive an average of $3.26 per hr. Laborers are paid an average of $3.03 per hr.

Using the above cost figures, the annual cost of solid waste collection in Yellowstone National Park has been estimated at $128,300 (Table III). The Chief of Maintenance for the Park has estimated the annual amount of waste collected in the Park to be about 1,750 packer loads of 13 cu yd each. If an average density in the packer is assumed to be 500 lb per cu yd, this is equivalent to about 5,700 tons of waste per year. The cost of solid waste collection in the Park is therefore estimated to be approximately $23 per ton.

Treatment and Disposal

The Park is presently using three incinerators and two open dumps for solid waste disposal (Figure 8). Each of these sites will be briefly described below.

TABLE III

ANNUAL COST OF SOLID WASTE COLLECTION IN YELLOWSTONE NATIONAL PARK

Type of Vehicles and Cost Factors	Peak Season (100 days)	Light Season (80 days)	Winter Season (185 days)	Total
Packer (6 units)				
Depreciation	$ 1,640	$ 1,310	$ 2,950	$ 5,900
Operation	5,540*	3,110	-	8,650
Labor	48,650*	26,700	-	75,350
Packer (1 unit)				
Depreciation	270	220	490	980
Operation	880	520	1,160	2,560
Labor	7,540	4,450	9,960	21,950
Stake (3 units)				
Depreciation	350	-	-	350
Operation	640	-	-	640
Labor	5,640	-	-	5,640
Pickup (4 units)				
Depreciation+	120	60	-	180
Operation+	340	150	-	490
Labor+	3,770	1,840	-	5,610
Total	$75,380	$38,360	$14,560	$128,300

*Includes 240 hr of overtime for the Fishing Bridge crew during the peak season.

+Fifty percent of time assigned to duties other than solid waste collection.

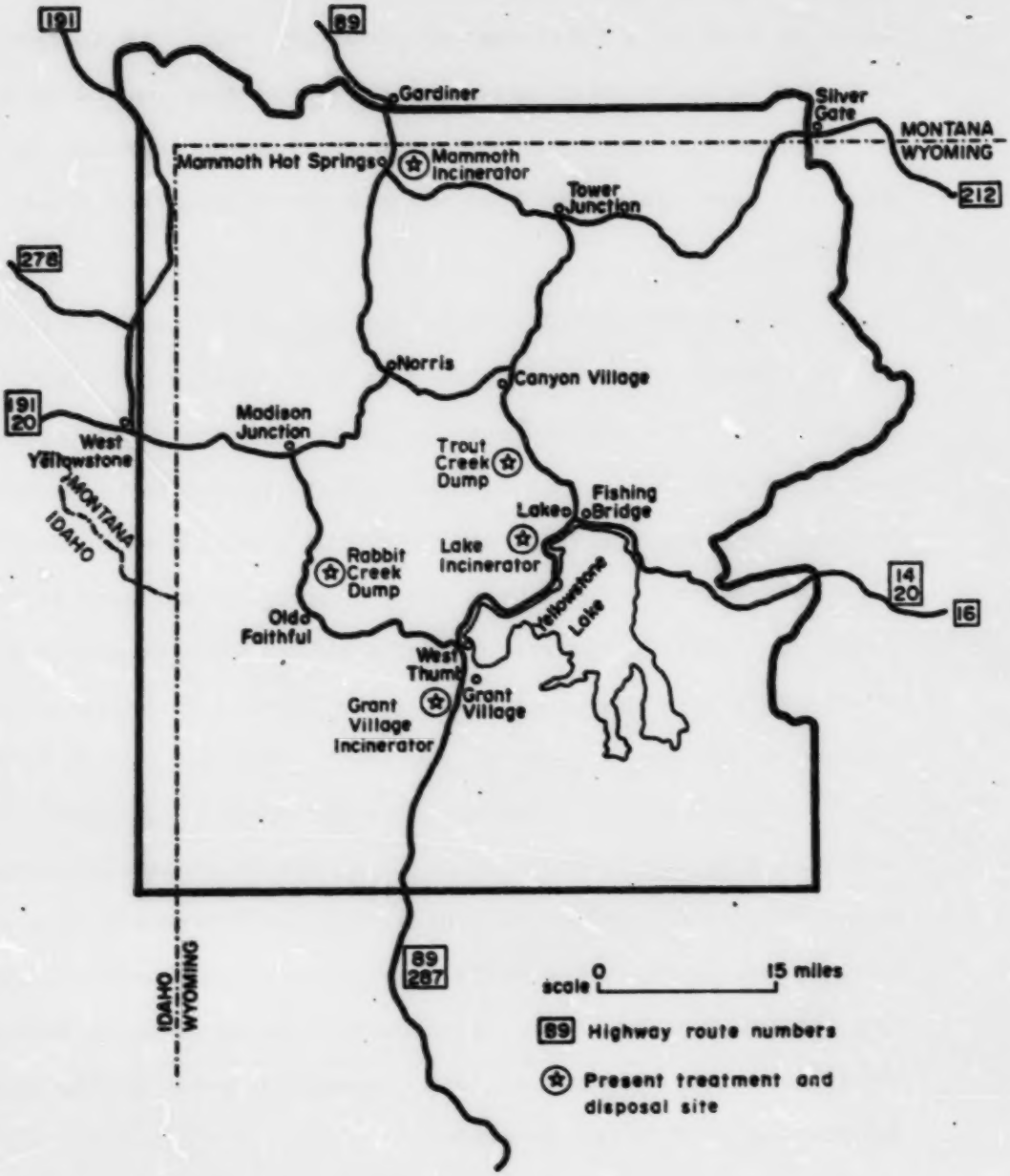

Figure 8. Solid waste treatment and disposal sites in Yellowstone National Park.

Mammoth Incinerator. The Mammoth incinerator (Figure 9) was built in 1963 at a first cost of about $93,000. Its design capacity is 3,000 lb of waste per hr, or 36 tons per 24-hr day. It is presently operated 8 hr per day. This incinerator is used all year and serves both Mammoth Hot Springs and Tower Junction.

Waste is dumped from collection vehicles onto a concrete pad and is then pushed into the furnace area by a front-end loader (Figure 10). The furnace area is about 8½-ft by 8½-ft by 8½-ft and lined with refractory bricks. Access to the furnace area is through the large guillotine-type charging door and the four cast-iron doors in the side. These side doors are used to insert rakes for stirring the waste and for raking the ashes into a wheelbarrow. Two fuel oil burners are used to help combustion. Furnace grates are stationary and are perforated, but no forced air is applied either above or below the waste. All draft is achieved from the movement of gases up the 80 ft refractory lined metal stack. Air pollution control equipment consists of a wire-mesh screen on the stack and a gravity settling chamber between the furnace and the stack. Residue is removed manually into a wheelbarrow and then dumped into a prepared trench at the site. Residue is usually not covered.

Monthly cost records have not been kept on the Mammoth incinerator since 1965, but the Bureau estimates the annual cost at $32,600

Figure 9. The Mammoth incinerator, Yellowstone National Park.

Figure 10. Front-end loader for charging incinerator.

(Table IV). Assuming that the Mammoth incinerator receives 480 packer loads per year, each containing 13 cu yd and 6,500 lb, this is 1,600 tons with an annual cost of about $20 per ton for treatment and disposal.

Lake Incinerator. The Lake incinerator (Figure 11) was completed in 1968 at a cost of about $100,000. Its design capacity is 3,000 lb of waste per hr, or 36 tons per 24-hr day. It is also operated 8 hr per day. The Lake incinerator receives waste from the campgrounds and picnic areas at Norris Junction, Canyon, Fishing Bridge and Lake. This incinerator is not operated during the winter. Its operational characteristics and design features are the same as the Mammoth incinerator.

Monthly cost records are being kept for the Lake incinerator, and have been combined into an annual cost of $21,000 (Table V). During the 5 months that this plant was in operation, it received about 100,000 standard cans of solid waste. Using the Bureau's assumed weight of 25 lb of waste per can, this is equivalent to about 1,200 tons of waste received. The cost per ton is then about $18 for treatment and disposal.

Grant Village Incinerator. The Grant Village incinerator (Figure 12) was completed in 1968 but was not used until the 1969 season. Its first cost was $100,000, and it has a design capacity of 3,000 lb of waste per hr, or 36 tons per 24-hr day, and like the others, operates 8 hr per day. This incinerator receives the

TABLE IV

ESTIMATED ANNUAL COST OF THE MAMMOTH INCINERATOR*, YELLOWSTONE NATIONAL PARK

Type of Cost	Amount ($)
Personnel -	
(1) Operator @ $3.26/hr =	7,560
(1) Laborer @ $3.03/hr =	7,030
Equipment -	
(1) Front-end loader @ $1.00/hr =	2,320
and $25.00/month =	300
Fuel - (estimate)	5,000
Supplies - (estimate)	1,000
Depreciation -	
(assume 10-year life)	9,300
Residue disposal	
(1) Tractor, crawler @ $2.00/hr =	30
(1) Operator @ $3.62/hr =	60
Total annual cost	32,600

*Operates 12 months per year

Figure 11. Lake incinerator, Yellowstone National Park.

Figure 12. Residue disposal at the Grant Village incinerator.

TABLE V

ESTIMATED ANNUAL COST OF THE LAKE INCINERATOR,*

YELLOWSTONE NATIONAL PARK

Type of Cost	Amount ($)
Personnel -	5,800
Equipment -	
Operating cost	700
Depreciation	300
Fuel -	3,330
Supplies -	1,400
Depreciation - (assume 10-year life)	10,000
Residue disposal -	
Equipment	40
Personnel	60
Total annual cost	$21,600

*Operates 4 months per year

solid waste from Grant Village and West Thumb. Its operational and design characteristics are the same as the Mammoth incinerator.

Monthly cost records have been kept for this season, and have been combined to show an annual cost of $15,200 (Table VI). This year the Grant Village incinerator received about 10,000 standard cans of solid waste and 20,000 compacted cans. This is approximately 800 tons of waste. The annual cost of treatment and disposal at the Grant Village incinerator is therefore about $19 per ton.

Trout Creek Dump. The Trout Creek dump is located in Hayden Valley between Canyon and Lake. It receives all of the kitchen waste from the hotels and lodges in Canyon, Lake, and Fishing Bridge. This location has been used as a dump site since 1953. Only the pit presently in use is uncovered (Figure 13) and it will also be covered over when it is filled with solid waste. This dump has been frequented by grizzly bears (Figure 14) since it was begun and these bears pose a hazard to the campgrounds in Canyon and Fishing Bridge.

No equipment is kept at this site. When the pit being used is filled, a dozer is brought in to cover the old pit and to dig a new one. It is estimated that the cost of bringing this equipment in is about $300 per year. Approximately 250 packer loads of waste are taken to this site annually. This is about 800 tons of waste, resulting in a disposal cost per ton of less than $1.

TABLE VI

ESTIMATED ANNUAL COST OF THE GRANT VILLAGE INCINERATOR,* YELLOWSTONE NATIONAL PARK

Type of Cost	Amount ($)
Personnel -	2,100
Equipment -	
Operating cost	400
Depreciation	300
Fuel -	2,000
Supplies -	300
Depreciation - (assume 10-year life)	10,000
Residue disposal -	
Equipment	40
Personnel	60
Total annual cost	15,200

*Operates 4 months per year

Figure 13. Trout Creek Dump, Yellowstone National Park.

Figure 14. Grizzly bears at Trout Creek Dump.

Conditions at this dump are very bad. The present pit has been excavated into the groundwater and waste is being deposited directly into the water.

Rabbit Creek Dump. The Rabbit Creek dump serves the Madison Junction and Old Faithful areas. It was begun in 1958, and a small tracked front-end loader is kept there and used to cover the waste about every other day. This dump also is popular with the grizzly bears.

The loader at this site is used about 360 hours per year (180-day season only). The cost of its operation is about $450 per year, the operator's salary amounts to $1,130, and equipment depreciation is $1,320 annually. There is an additional cost of about $300 per year to bring in larger equipment to excavate the pit. This is an estimated total annual cost of $3,200. It is estimated that this dump receives about 360 packer loads of waste annually. At 13 cu yd per load and 500 lb per cu yd, this is approximately 1,200 tons of waste per year. The annual cost of disposal at the Rabbit Creek dump is then about $3 per ton.

Summary. Present solid waste treatment and disposal practices at Yellowstone National Park cost an estimated $72,900 (Table VII) per year but are inadequate and in need of major improvement. The three incinerators are not acceptable either in terms of waste

TABLE VII

ESTIMATED ANNUAL COST OF SOLID WASTE TREATMENT AND DISPOSAL IN YELLOWSTONE NATIONAL PARK

Disposal Facility	Annual Cost	Tons of Waste Treated	Annual Cost per Ton
Mammoth incinerator	$32,600	1,600	$20
Lake incinerator	21,600	1,200	18
Grant Village incinerator	15,200	800	19
Trout Creek dump	300	800	1
Rabbit Creek dump	3,200	1,200	3
Total	$72,900	5,600	$13

disposal or operator safety. Both dumps are unsanitary, unsightly, and major bear attractants.

In addition to the problems stated above, the solid waste treatment and disposal facilities and practices in Yellowstone National Park are in violation of Part 76 of Subchapter F of Title 42, Code of Federal Regulations. Specifically Section 76.8, (b)(3) which states that "Wastes shall not be left in open dumps," and Section 76.8, (c)(1) which states in part "... for installations burning more than 200 lb of waste per hr, emissions shall not exceed 0.2 gr of particulate matter per standard cubic foot (scf) of dry flue gas corrected to 12 percent carbon dioxide (without the contribution of carbon dioxide from auxilary fuel)..." It must be recognized, however, that the facilities and practices used in Yellowstone were developed over a period of time, and because of financial restrictions it will require additional time before they are completely corrected. The Park Service must begin immediately, however, to work toward an acceptable solution to the solid waste disposal problems in Yellowstone National Park.

SUGGESTED FUTURE SOLID WASTE DISPOSAL PRACTICES

It should be the goal of Yellowstone National Park to abide by Federal standards regarding solid waste treatment and disposal. In addition to conforming to the intent of the regulations, the Park Service has the added responsibility of maintaining as natural an environment within the Park as is possible. Therefore, the Park Service must not only operate treatment and disposal sites with the highest standards but they must choose the type and location of these facilities with equal care so as not to endanger the environment.

Interim Measures

The National Park Service must progress from the present situation in the Park to a system of solid waste disposal sites that are in keeping with their future goals. The closing of all open dumps should be given top priority because of their obvious threat to the natural ecosystem. As a first step, the closing of existing dumps and the establishment of sanitary landfills on the same sites will be discussed.

Trout Creek. The waste now in this dump should be spread, compacted and then covered with at least 2 ft of compacted earth. If

there is still water in the pit at the time of its closing, additional earth may be necessary in order to fill the pit at least 2 ft above the anticipated high groundwater level.

If it is assumed that the Trout Creek sanitary landfill will receive two packer loads (26 cu yd) of solid waste each day for 100 days, and one packer load per day, 5 days a week for an 80-day period, this will amount to about 260 loads of waste per year. Reported densities of solid waste in sanitary landfills range from 400 to 1,200 lb per cu yd. In the interest of making a conservative estimate, it is assumed that the density obtained in the landfill will only be 500 lb per cu yd. It must be recognized, however, that the actual density will depend upon the type of waste, the equipment used, and the care exercised in operation. Achievement of a higher density will result in less land utilization.

Three methods of sanitary landfilling could be used at the Trout Creek site. These are the area, ramp, and trench techniques (Appendix C). The area method (Figure 15) could be used on top of the present fill area. Its use would probably require the excavation and hauling of cover material from other parts of the site.

As Figure 15 shows, the waste is dumped at the bottom of the fill and each load is then spread up the working face and compacted by

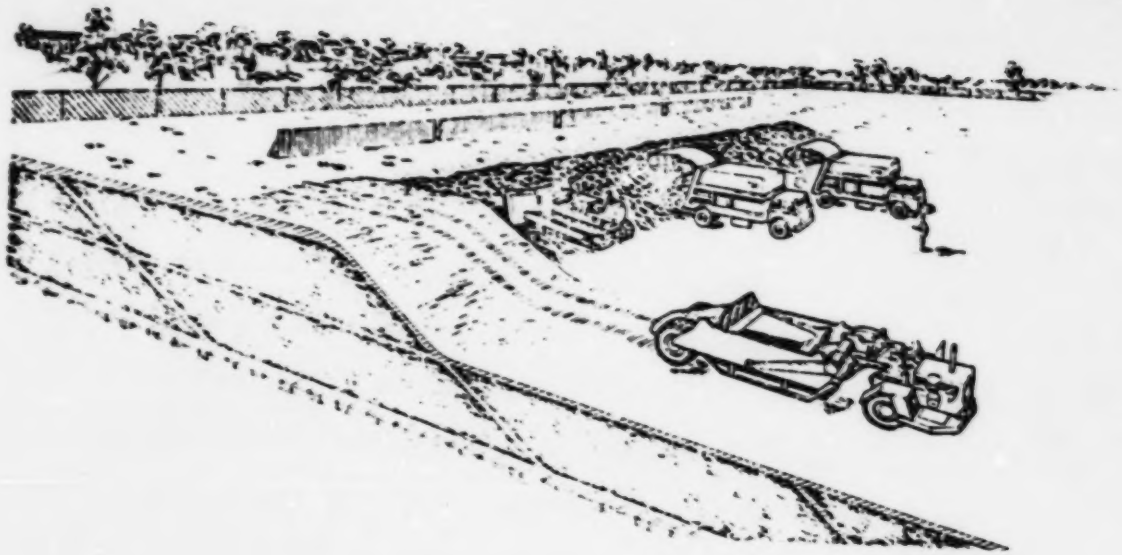

Figure 15. Area method of sanitary landfill operation.

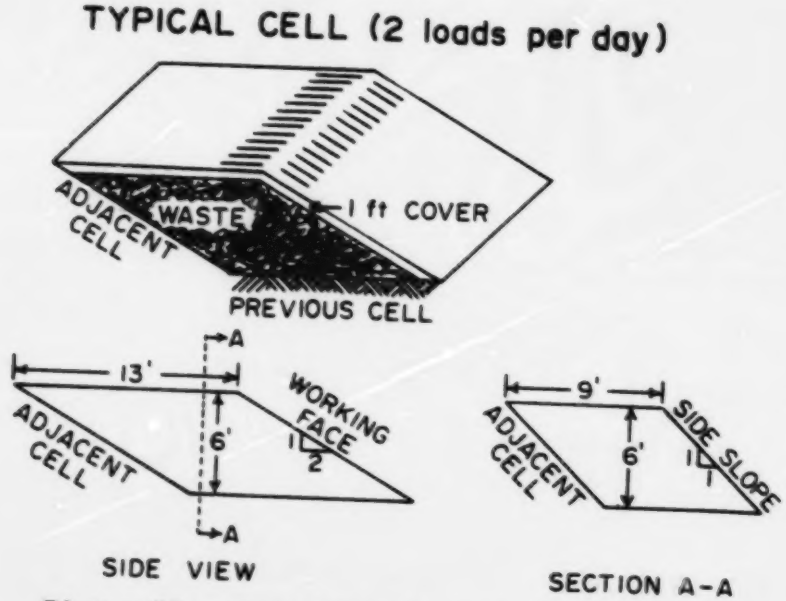

Figure 16. Area landfill cell dimensions.

the landfill equipment. The slope of the working face should be maintained at about two to one. The width of all cells should be limited to about one blade width (or about 9 ft for the equipment likely to operate this site). Normal maximum cell depth is about 8 ft, but that depth cannot be obtained with the small amount of waste received each day at Trout Creek. The optimum depth of fill will be 6 ft for two packer loads (26 cu yd) of waste per day and 4.5 ft for one packer load (13 cu yd) per day. The length of the top of the cells under these two operational conditions will be 13 ft (Figure 16) and 9 ft respectively.

Cover material available at the Trout Creek site is granular and is not expected to produce a satisfactory seal if the normal cover depth of 6 in. of compacted material is used. Therefore, it is estimated that at least 1 ft of compacted cover will be used (Appendix D). The amount of cover material necessary to seal the top, working face, and side slope of the landfill at the end of each day's operation will be about 13 cu yd for a two-load cell and about 9 cu yd for a one-load cell.

The total volume of waste received each year will be 3,300 cu yd, and 1,700 cu yd of cover material will be required. If filling is carried out to a height of 7 ft (6 ft + 1 ft of cover), the land required will be about 2,100 sq yd, or 50 yd by 45 yd. Filling could also be done

to a height of about 12.5 ft if one-load cells are constructed on top of two load cells. This would require an area of 1,200 sq yd, or a site of 30 yd by 40 yd.

The ramp method of sanitary landfill operation (Figure 17 could also be used at the Trout Creek site. The operation of a ramp landfill varies from an area fill in that cover material is excavated from in front of the fill. Therefore, this method could not be used where filling has already been done. Waste is dumped and compacted as for the area fill method and the volume of waste and cover material will be the same, as will the land requirements.

The trench technique (Figure 18) could also be used at this site. This method could only be used, however, if the bottom of the trench could be kept above the groundwater. The method of operation is to excavate a trench as deep as possible and about twice as wide as the landfill equipment used. Waste is then dumped into the trench, compacted and covered. The material excavated from the trench can be used as cover material for the waste.

If a trench were constructed 12.5 ft deep and 18 ft wide two lifts could be placed in it, a 4.5-ft lift for a one-load cell and a 6-ft lift for a two-load cell. This would require about 5 cu yd of cover

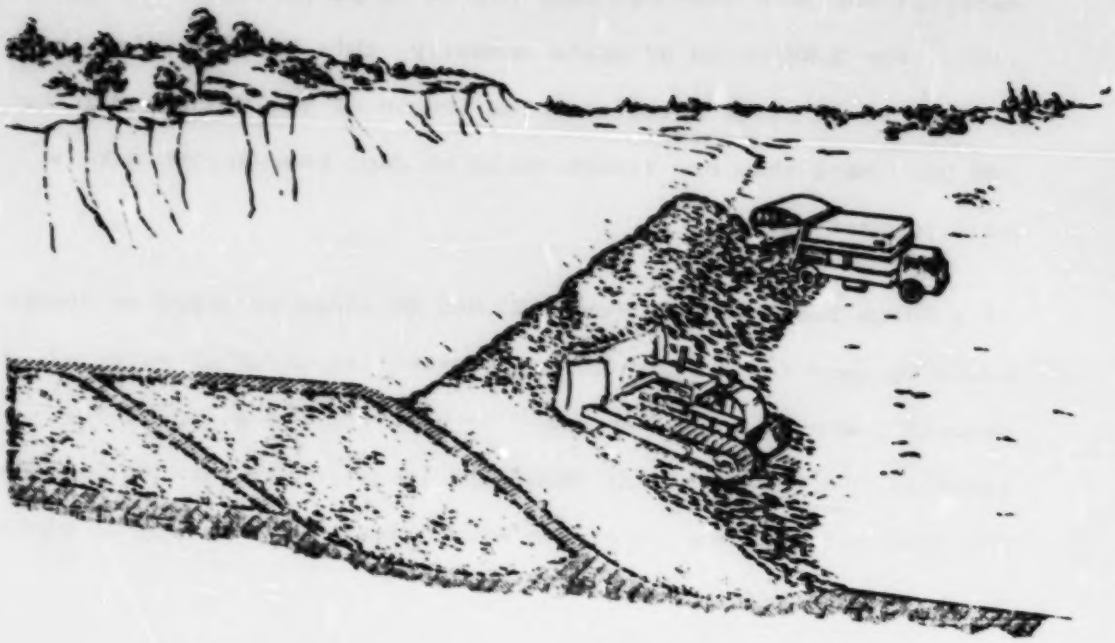

Figure 17. Sanitary landfill by the ramp method.

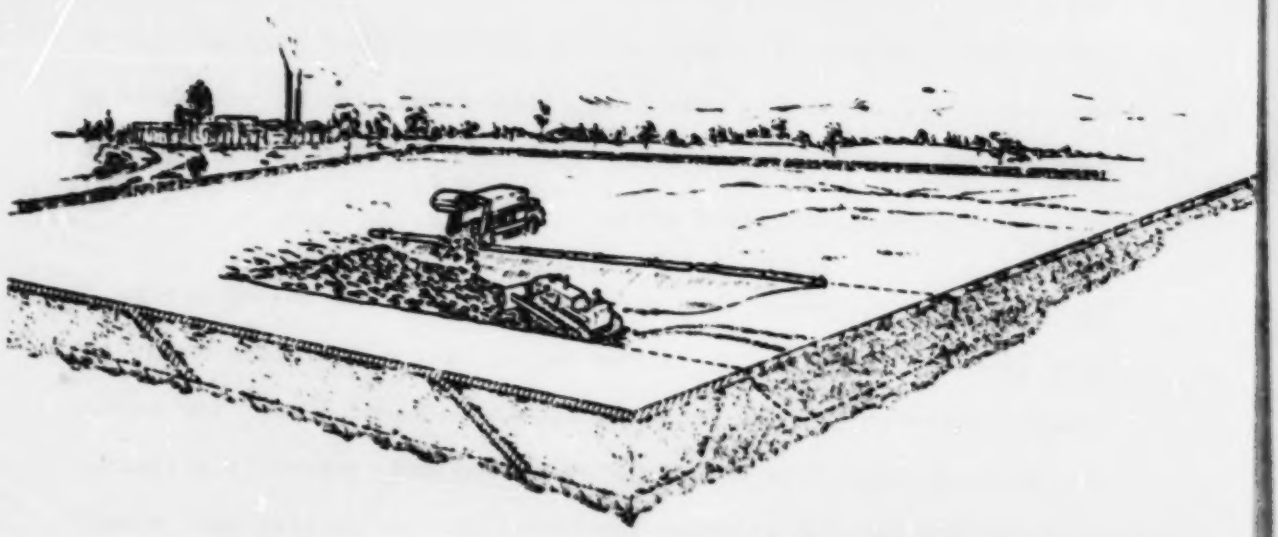

Figure 18. Trench operation of a sanitary landfill.

material for each one-load cell and 10 cu yd for each two-load cell. For 3,300 cu yd of waste annually, this would require about 1,200 cu yd of cover material. The length of the trench would be 180 yd. More than one trench could be dug, however, to make a more compact site.

If a large piece of equipment (30,000 lb class of dozer or loader) could be used for excavation and stockpiling of cover material, a smaller piece of equipment could be used for operation of the landfill. A rubber-tired, front-end loader would seem to be ideal for this purpose because of the flexibility of this type of equipment.

A fence will be necessary at this site to keep the bears out of the waste. The best type of fence and its dimensions would probably have to be determined by field trials. It would seem, however, that a chain-link fence with a slanted barbed wire barrier on top would be necessary. Some provisions would also be necessary to keep the bears from digging under the fence, either an underground extension or an electrified wire.

Rabbit Creek. Although this site is not ideal for the operation of a sanitary landfill, it is the desire of the Park management to remain operating at this location for the present time. The waste presently at this site should be compacted and covered in preparation for beginning a sanitary landfill. Either an area or a trench type landfill could be operated at this site.

An estimated 360 packer loads of solid waste are disposed of in the Rabbit Creek dump each year. Therefore, it is expected that three loads per day will come during 100 days of the peak season, and one load will come during each collection day of the 80-day light season.

If the area fill technique is used, the average cell dimensions for one load of waste will be the same as those calculated for Trout Creek, or nominally 4.5 ft by 9 ft by 9 ft. If the cell width is kept at 9 ft and the height at 6 ft (Figure 16), the length of the top will be about 19.5 ft. These two sizes of cells will respectively require 9 cu yd and 15 cu yd of cover material. This will require a total landfill volume of 6,600 cu yd. The height of the fill will probably have to be limited to 7 ft (including cover) at this site because of the underlying rock formations that limit the availability of cover material. If this is so, then the fill will cover an area of 3,300 cu yd each year. This is equivalent to a site about 50 yd by 60 yd.

A trench operation, again to a height of 6 ft and 20 ft wide, would require 6 cu yd of cover material for each single load, and 13 cu yd for each triple load. The total annual volume of the trench would be 6,300 cu yd, and it would be about 500 yd in length. Again, multiple trenches could be used.

The small piece of equipment presently at this site could be used for daily operation if a large tractor was brought in as needed to

excavate the cover material. Fencing requirements would be the same at this site as at the Trout Creek site.

Incinerators. Ultimate disposal of the residue from the three incinerators could continue to be on-site for the present time. The tractors used for charging the furnaces, however, should be used to cover residue that contains organic material after removal from the incinerators. These organic materials should be placed in prepared trenches and covered with earth.

Costs. The cost of implementing and operating these interim practices would certainly be higher than the present cost of solid waste treatment and disposal, but it is a cost that must be met. Incinerator costs should not increase, because the equipment and operators needed under the new system are already charged to solid waste treatment and disposal. The major cost increase will be at the Trout Creek landfill where there is presently no equipment operating. The estimated annual cost of landfill operation will be about $7,300 at each of the two landfills or $14,600 (Table VIII). This assumes operation 8 hr per day for 160 days per year.

The annual cost of the proposed system would be about $84,000, or $11,100 above the $72,900 presently being spent. This is an increase in disposal cost from $13 per ton to about $15 per ton.

TABLE VIII

ESTIMATED ANNUAL COST OF TWO SANITARY LANDFILLS

YELLOWSTONE NATIONAL PARK

(With three incinerators remaining in use)

Type of Cost	Amount ($)
Personnel -	
Two operators @ $3.26/hr =	8,360
Equipment -	
Two front-end loaders @ $1.25/hr =	3,200
and $110.00/month	2,640
Two large tractors and operators for site preparation (estimate)	400
Total*	14,600

*This cost is exclusive of costs associated with fencing of the site and road construction. These costs, particularly fencing, will be significant and should be determined.

It is doubtful if operation at either of the proposed landfills would take 8 hr per day. Therefore, one operator could possibly be used to service both sites. A pickup truck could be used by the operator to travel the 50 miles between the two sites. The annual cost of this type of operation would be about $7,600 (Table IX). This increases the total treatment and disposal cost by $4,100 per year to about $77,600 or $14 per ton. This type of scheme perhaps could not work if traffic prohibited the free movement of the operator from one site to the other.

Future Planning

It is doubtful if the three incinerators operated in Yellowstone National Park meet Federal air pollution requirements and they should be modified so as to meet them or they should be abandoned. It is believed that the cost involved in adding the necessary air pollution control equipment would be unreasonable in view of the cost of operating an acceptable sanitary landfill. Further, the composition of noncombustibles in solid waste generated by camping and picnicking has been estimated at 33 percent and 27 percent respectively.[1] The estimated amount of noncombustible material in solid waste from residences is 22 percent.[2] Since these are the three predominant sources of incinerated waste in the Park, it would appear that at least one-quarter of the waste treated by incineration will remain after burning. The actual amount will

TABLE IX

ESTIMATED ANNUAL COST OF TWO SANITARY LANDFILLS
WITH ONLY ONE OPERATOR, YELLOWSTONE NATIONAL PARK
(With three incinerators remaining in use)

Type of Cost	Amount ($)
Personnel -	
(1) Operator @ $3.26/hr =	4,180
Equipment -	
(2) Front-end loaders @ $1.25/hr =	1,200
and $110.00/month	2,640
(1) Pickup truck @ $0.045/mile	70
and $18.00/month	110
(2) Large tractors and operators for site preparation (estimate)	400
Total*	7,600

*This cost is exclusive of costs associated with fencing of the sites and road construction to the sites. These costs, particularly fencing, will be significant and should be determined.

probably be somewhat greater because of incomplete burning of the combustibles. If only one-fourth of the incinerated waste remains, however, this amounts to 900 tons of waste each year that must be disposed of after incineration. It can be seen that incineration is, at best, only a partial solution to the problem of solid waste disposal. Therefore, it is suggested that sites for sanitary landfills be selected for use when the incinerators are closed.

The Mammoth incinerator is in need of major repairs at the present time, and it may be well to begin operation of a sanitary landfill in the Mammoth Hot Springs area in the near future. Two possible sites have been identified in the area. One is off of the Old Gardiner Road in the Elk Plaza region and the other is off of the Tower Junction Road near the Patrol Cabin on Blacktail Deer Creek (Figure 19). The Elk Plaza site appears desirable (Appendix B) because of its closeness to Mammoth Hot Springs.

When the Lake incinerator is closed, a good potential site for a sanitary landfill, other than Hayden Valley (Trout Creek), would be in Pelican Valley (Figure 19). If Pelican Valley were to be used, and the Trout Creek landfill closed, it would probably be necessary to establish another sanitary landfill closer to Canyon Village. The former Grebe Lake gravel pit west of Canyon (Figure 19) should be a prime site for consideration in this area.

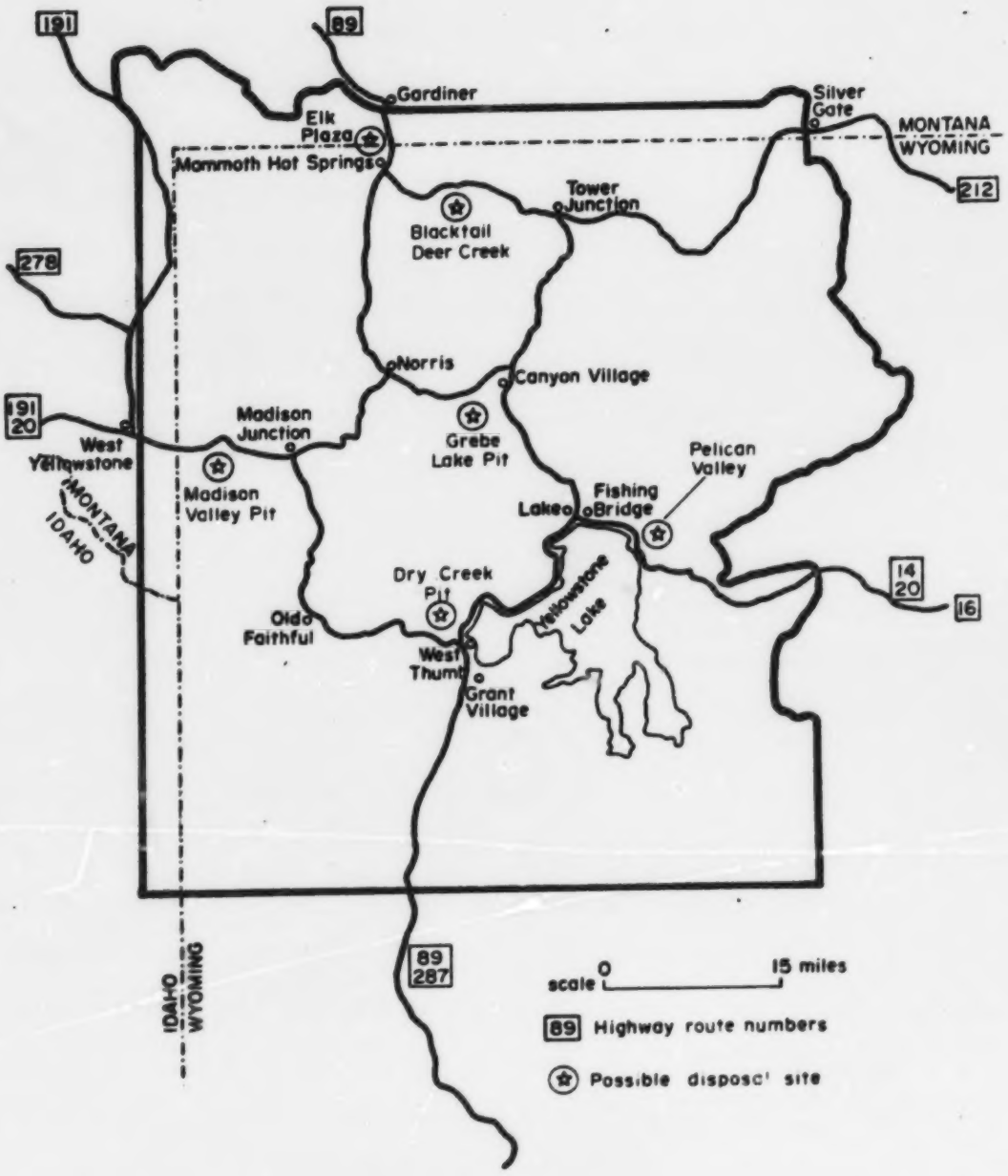

Figure 19. Proposed disposal sites, Yellowstone National Park.

The former dump site in the Grant Village area could be used as a sanitary landfill when that incinerator is closed. That site in the Dry Creek pit (Figure 19) could also possibly be used by collection trucks from the Old Faithful area, and the Rabbit Creek landfill could be closed. If the hauling of waste from Old Faithful across the Continental Divide to Dry Creek is not feasible, the Grebe Lake site could possibly be used although this would require a haul of about 35 miles each way. A better solution, if Rabbit Creek is closed, is the establishment of a sanitary landfill in the abandoned Madison Valley gravel pit (Figure 19) to serve both Old Faithful and Madison Junction.

Before additional sanitary landfills are established, however, further engineering investigations should be made of all potential sites (Appendix B). Particular care should be taken in areas having porous soils so that groundwater pollution does not occur.

Rather than establishing four or five sanitary landfills in the Park, it may be more economical to operate a central disposal facility (either a sanitary landfill or an incinerator) and haul the waste in from all areas of the Park. This would probably require a change in the type of collection vehicles used, or the use of transfer stations, in order to reduce the haul cost associated with central disposal. It is possible that the U. S. Forest Service, Gallatin National Forest, Gallatin County, Montana, and

the community of West Yellowstone, Montana might be interested in joining Yellowstone National Park in a joint solid waste disposal system. This possibility should at least be investigated.

ACKNOWLEDGEMENTS

The information contained in this report was collected with the help of the personnel of Yellowstone National Park. Thanks must be given to Mr. Jack K. Anderson, Superintendent; Mr. Gary E. Everhardt, Assistant Superintendent, Operations; Mr. William E. Hape, Maintenance Supervisor; Mr. Glen F. Cole, Field Research Biologist; and Mr. James H. Batzloff, North District Maintenance Supervisor for their cooperation in this effort.

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APPENDIX A

A Bear Management Policy and Program for Yellowstone National Park

A report to the Director by the Natural Sciences Advisory Committee of the National Park Services, as a result of a meeting in Yellowstone National Park, September 6 and 7, 1969.

A. Starker Leopold, Chairman
Stanley A. Cain
Charles E. Olmsted

PREAMBLE

Yellowstone has an estimated population of about 250 grizzly and 500 black bears. Management goals, consonant with the administrative policies of the National Park Service, may be summarized as follows:

1. To maintain populations of grizzly and black bears at levels that are sustainable under natural conditions as part of the native fauna of the Park.
2. To plan the development and use of the Park so as to minimize conflicts and unpleasant or dangerous incidents with bears.
3. To encourage bears to lead their natural lives with minimum interference by humans.

The present meeting was called because, in fact, the above goals of bear management have not been fully met. A long history of

dumping garbage and refuse in open pits has attracted many grizzly bears and substantially altered their natural wild habits. Inadequate trash cans in earlier years became habitual sources of food for both grizzly and black bears, and this in turn led to the bears learning to raid food sources in camps and automobiles. Roadside feeding of black bears by visitors, while against Park regulations, has persisted to the extent that many individual bears have become confirmed panhandlers. Personal injuries and cases of property damage are occurring with such frequency that a number of bears have had to be destroyed. The problem has assumed critical significance -- legal, political, and otherwise. The National Park Service must act decisively to correct this state of affairs. The report which follows suggests a possible sequence of management steps to begin rehabilitating the bears to a wild, natural existence.

This Advisory Committee does not pretend specific competence in judging the ethology and psychology of bears. However, we had the advantage of published and verbal testimony of experienced park administrators and bear biologists including the following Consultants for our Yellowstone meeting: John and Frank Craighead, Albert Erickson, and Frederick C. Dean. The recommendations here presented were distilled from the collective testimony of all who contributed to the meeting.

PROCEDURES

1. Garbage disposal

The ultimate objective agreed upon by all participants, is the incineration or sanitary disposal of trash and garbage in a manner that will completely isolate this food source from bears. Ideally all refuse should be hauled out of Yellowstone National Park for incineration and burial. Future plans for such a program of disposal are being considered now.

But in the meantime, there is disagreement as to the sequence of steps leading to the elimination of garbage from availability to grizzlies. One view is to cut off all garbage quickly, forcing the bears to turn immediately to natural foods. The opposite contention is to phase out garbage feeding over a period of time, "weaning" the bears gradually. The issue hinges on which of these procedures will result in the least number of bears going into camp grounds. Unfortunately, prognosticating how garbage-fed grizzlies will respond to deprivation depends on judgement rather than data. Much is known about the habits of garbage bears and of wild-living bears, but little is known about the process of transition. In any event, the transition must be made, and everything possible done to protect both park visitors and the population of bears during the process.

Practical budgetary limitations have precluded immediate elimination of garbage. But a start has been made in sorting refuse at Trout Creek Dump and incinerating combustibles. This has led to a modest decrease in grizzly use, with a corresponding increase in bear visitations to Rabbit Creek Dump. There has been an apparent increase in grizzly visitations to camp grounds in the central portion of Yellowstone and increased control of troublesome bears (killing as well as trapping). When Trout Creek dump is completely closed, how will the grizzlies respond? And what will transpire when the other dumps are closed as well?

On the assumption that one reaction of some of the bears will be to gravitate into camp grounds, we suggest the following list of camp ground protection practices.

2. Camp ground protection practices

a. Intensified sanitation. - All trash cans at campgrounds and along roads are now bear-proofed. But there should be increased emphasis on maintaining clean camping areas. Every known procedure and device should be employed to eliminate all smells or materials that might attract bears.

b. Public education and patrol - Much emphasis should be added to the information campaign about camp sanitation and security. Road signs, printed hand-outs, verbal instruction at campfire programs,

and enforcement of camp ground regulations should be intensified to assure maximum cooperation of the public. Campers require repeated admonitions to store food in plastic containers, locked in their automobiles.

c. Patrol. - Trained and equipped night patrolmen in automobiles should be assigned to all campgrounds where bear troubles are imminent. Their function would be to urge and enforce sanitation procedures, to detect the presence of bears in campgrounds, to discourage them in every possible way short of inciting anger, and to radio for help if a bear requires removal by drug or other means.

d. Scare devices. - The Park Service should be testing every possible device to keep bears away from campgrounds -- sonics, lights, mace or other gases, repellent odors, etc. These tests should not be conducted at a campground but rather at some isolated point with bait of some kind (carrion, for example).

e. Bear fencing. - Experimental fencing should be tested to seek a bear proof combination. Link fence enclosed with parallel electric wires -- one high, one low -- might be a combination to try. Such drift fence placed across areas where bears gain access to campgrounds might deflect the bear traffic. Funnel exit gates should be provided to permit bears to leave the enclosed area if they should happen to get inside.

f. Carrion feeding. As a substitute for garbage, carrion might be placed to draw bears away from campgrounds. Dropped by helicopter in outlying districts, the carcasses of surplus beasts (emaciated park ungulates, slaughter house surpluses, etc.) may help reduce the concentration of grizzlies around areas occupied by people, particularly during the transition period of closing the dumps.

g. Closing campgrounds. - If necessary, campgrounds situated in the vicinity of garbage dumps could be closed during the transition period.

h. Relocation of campgrounds. On a longer scale, the location of all campgrounds should be re-examined to see if some may be poorly located from the standpoint of bear visitation. Even long after the garbage problem is resolved, some camp areas may naturally attract passing bears. These had best be moved.

3. Study of bear reaction to garbage removal

To guide the development of the bear management program, each succeeding step should be studied concurrently to note reaction of the bears. Investigations should concentrate particularly on the following:

a. Movements of bears already marked or instrumented. Many bears around Trout Creek Dump have been captured and marked. Response of these individuals to elimination of garbage will suggest what problems may arise as other garbage sources are removed.

b. Recording numbers and density of bears at all dumps as food sources are pinched off.

c. Monitoring human contacts with grizzlies, both threatening and casual, at camp grounds and elsewhere during this transition.

It is to be emphasized that these studies are merely adjuncts to an active management program and are no substitute to continuing, long-term research on the grizzly (mentioned later).

4. Dealing with troublesome bears

Despite all precautions, safeguards, and discouragements, some bears will doubtless persist in visting campgrounds. Initial treatment of these animals is trapping and transplanting. If this procedure fails, and the individual animals prove to be a continuing threat to human lives or property they may have to be destroyed.

a. Transplating bears. When a troublesome bear is transplanted, every possible effort should be made to make the initial transplant

succeed. If the first release is in wild but hospitable terrain, far from human habitation, the animal may be successfully acclimated, particularly a young animal. In the past, many trapped bears have been released at convenient points near roads or border stations, where they quickly gravitate back to camp searching. Helicopter transport, though costly, may be one effective way to assure successful transplantation.

b. Destroying incorrigible bears. In the past 10 years, the Yellowstone Park Administration has felt obligated to destroy about 30 black bears and four grizzly bears per year. If present plans succeed in eliminating the linkage between bears and human sources of food, this program may drop ultimately almost to zero. But in the transition period the Park should be prepared to eliminate bears that prove to be incorrigible and dangerous to human life. Hopefully, the number will be few and hopefully the men making decisions will take the right animals at the right time and will spare individuals that are capable of rehabilitation. The bodies of such animals as killed should be fully utilized for scientific purposes.

These steps are fully in accord with administrative policies which state that animal control, when necessary shall be undertaken as follows: (1) live-trapping for transplanting elsewhere; (2) scientific research specimens; and (3) direct reduction by National Park Service personnel.

5. Continuing Research

During the past 11 years, the grizzly population of Yellowstone has been under continuous study by John and Frank Craighead. A number of publications and reports, including a 113-page report, Management of Bears in Yellowstone National Park, have been made available to the National Park Service and other agencies administering grizzly populations. Much data on grizzly bear biology accumulated in this study are as yet unpublished due to the long-term nature of the research. Early publication is urged.

Additional studies have been undertaken in more recent years of both grizzly and black bears in the northern Rocky Mountain region. These investigations should be supported and extended. For example, surveys of the grizzly populations in Wyoming and Montana outside of the national parks should be undertaken jointly by interested state and federal agencies. All possible data should be derived from bears killed during legal hunting seasons. Studies of bear/human contacts undertaken in Glacier and Yellowstone Parks should be continued and extended. A successful future management program of wild bears will call for all the information that can be assembled.

6. Financing the bear program

The emergency program of bear management suggested here cannot be funded out of regular appropriations for Yellowstone Park. Garbage

elimination, manpower, helicopter rental, automobile patrol, and experimental materials for fencing or repelling bears will call for a special supplementary budget from the National Park Service. We urge the Director to seek emergency funds for this purpose and to implement plans now for the period of bear emergence from winter quarters in the spring of 1970. An estimate of costs should be obtained from the Superintendent of Yellowstone National Park.

Attending September 6 meeting in Yellowstone

Natural Sciences Advisory Committee

Dr. A. Starker Leopold (Chairman), University of California
Dr. Stanley A. Cain, University of Michigan
Dr. Charles E. Olmsted, University of Chicago
Mr. Sigurd Olson, Ely, Minnesota (absent)

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Mr. Jack K. Anderson, Superintendent, Yellowstone
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Mr. William J. Barmore, Research Biologist, Yellowstone
Miss Margaret M. Meagher, Research Biologist, Yellowstone
Mr. Richard G. Prasil, Management Biologist, Alaska Field Office

APPENDIX B

SANITARY LANDFILL SITE SELECTION, YELLOWSTONE NATIONAL PARK

In selecting a site for use as a sanitary landfill, certain information will have to be gathered and certain decisions must be made. The procedures used to obtain the necessary data, and how they affect the decisions, will be discussed below.

Land Requirements

The method of landfilling used, the size of the population generating the waste, the number of years the site is used, and the quality of the operation will all influence the amount of land, actually the usable volume, necessary for operation of a sanitary landfill. The amount of waste collected in the Park has been estimated for the different developed areas (Table B-1). Additional information on the amount of solid waste collected from recreation sources has been gathered nationally (Table B-2). It is assumed that this waste has a density of about 500 lb per cu yd when delivered to disposal sites.

Reported densities of waste in sanitary landfills range from 400 to 1,200 lb per cu yd. A value of about 500 lb per cu yd will probably be reasonable for fills in Yellowstone because it is believed that relatively small pieces of equipment will be used on the fills and that a high degree of compaction will not be obtained.

TABLE B-1

ESTIMATED AMOUNTS OF SOLID WASTE COLLECTED, YELLOWSTONE NATIONAL PARK

Area	Main Season (100 days)		Light Season (80 days)	
	packer loads/day	cu yd/day	packer loads/day	cu yd/day
Canyon	2	26	-	-
Grant Village	2	26	1	13
Lake	4	52	1	13
Madison	1	13	-	-
Mammoth*	3	39	1	13
Old Faithful	2	26	1	13
Total	14	182	4	52

*Operates the remainder of the year at 1 load per day

Source: Chief of Maintenance, Yellowstone National Park (5/9/69)

TABLE B-2

ESTIMATED AMOUNTS OF SOLID WASTE COLLECTED

FROM SELECTED RECREATION ACTIVITIES

Source	Amount Collected
Campgrounds	1.26 ± 0.01 lb per camper/day
Picnic grounds	0.93 ± 0.03 lb per picnicker
Cabins (with kitchens)	1.46 ± 0.18 lb per occupant/day
Rooms (without kitchens)	0.59 ± 0.23 lb per occupant/day
Restaurants	0.7 lb per meal served
Observation sites	0.05 ± 0.02 lb per incoming
Visitor centers	0.02 ± 0.002 lb per visitor
Administrative residences	1.37 ± 0.27 lb per occupant/day

Source: Spooner, C. S., Study of recreation solid wastes for the U. S. Department of Agriculture Forest Service. Public Health Service Publication No. 1991. Washington, U. S. Government Printing Office, 1969. 134 p. (In press.)

The ratio of the volume of waste to the volume of cover material in a completed sanitary landfill is usually about four to one. Because of the small amounts of waste that will be received at some landfills and the need for a greater depth of cover material on each cell, it is felt that this ratio will often be about 2:1 and that a ratio of 3:1 should be used for design purposes.

Fencing, roads, and certain facilities must all be provided at a sanitary landfill, therefore, a new fill should generally be located in a site that has a potential life of at least 5 years.

For example, a site to serve as a landfill for the Mammoth area should have potential usable volume of:

$V_T = (D_m\ Y_m + D_L\ Y_L + D_R\ Y_R + 1/4\ V) \times N$, where

V_T = Total volume to be used for sanitary landfill,

D_m = Number of days in the main season,

D_L = Number of days in the light season,

D_R = Number of days in the remainder of the year,

Y_m = Cubic yards of waste per day in main season,

Y_L = Cubic yards of waste per day in light season,

Y_R = Cubic yards of waste per day for the remainder of the year,

V = Total volume of waste per year, and

N = Number of years site is to operate.

$$V_T = [100\ (39) + 80\ (13) + 185\ (13) + 1/4\ (7{,}345)]\ \times 5$$

$$V_T = 46{,}000 \text{ cu yd.}$$

The volume required in other areas can be calculated in a similar manner. The method of operation used, and the characteristics of the site (as will be discussed later), will determine the depth to which filling may be done, and also the land area required.

Characteristics of Surrounding Areas

The use, or the intended use, of the land surrounding a proposed landfill site is very important. It would not be desirable, for instance, to locate a fill in a scenic area or where visible from main roads. The accessibility of the site is another important consideration, however, and a balance must be achieved between isolation of the site and nearness to waste generation areas.

Solid waste collection vehicles are usually large and difficult to maneuver, therefore, a sanitary landfill should be accessible on roads that are wide enough and strong enough, that are open during all weather conditions, and that do not have excessive grades. The haul distance from collection points to a sanitary landfill is something that should also be considered in site selection. As a general rule, the shorter the haul distance, the lower the cost. The time involved in haul to different landfill sites will need to

be determined in light of the delays caused by the traffic in the Park.

Cover Material

Cover material should be both readily accessible and suitable for sanitary landfill operations. The type of soil can vary widely without imparing the quality of operation. Soil such as sandy loam, that has good workability and compaction characteristics, is the most desirable for cover material. There is a shortage of good cover material in Yellowstone National Park, however, and a soil less desirable than sandy loam will often have to be used. Additional care will be needed in operation of such sites to insure that sufficient soil of the type available is applied as cover material to form a tight seal over the waste. The best soil in Yellowstone is most likely to be located in the alluvial valleys. It is felt that at least 1 ft of cover material will be needed in most cases, because of the granular nature of the soil in the Park.

Geology

Sanitary landfills have the potential of causing ground and surface water pollution if care is not taken in the design and

operation of the site. The groundwater level should be located and filling should be confined to well above the highest anticipated level. Normal practice is to remain from 2 to 5 ft above the groundwater. The topography of all sites should also be investigated to determine potential flooding conditions of the site during heavy rains and snow melts. If these conditions could arise, special consideration will be needed in the design of the site.

Climate

Operation of landfills in Yellowstone National Park will usually be done only during the summer months. Therefore, most potential climatical problems will be associated with heavy rainfall. It must be recognized that a sanitary landfill must be operated every day on which waste is deposited, and that it cannot be closed because of the weather. An area must be selected where operational problems will not occur.

One sanitary landfill may be operated year-round in the near future. Special provisions may be needed at this site to insure trouble-free operation during the winter. These will usually consist of doing all necessary excavation before the ground freezes and stockpiling cover material for later use.

APPENDIX C

SANITARY LANDFILL DESIGN, YELLOWSTONE NATIONAL PARK

After a site has been selected for a sanitary landfill, a plan of operation and a design for that particular site should be prepared. The elements of this plan are discussed below.

Topographic Map

A topographic map of the site should be prepared, with contour intervals not exceeding 5 ft, to show the existing characteristics of the area. This map will be used to locate the fill and borrow areas, to locate the necessary utilities and facilities, and to design the final contours of the completed landfill in keeping with the topography of the surrounding area. One thing that must be kept in mind is the routing of surface water around and over the site during operation, and also after filling is completed.

Site Improvements

Before operation of the landfill begins, the site should be cleared of trees and shrubs. Only an area large enough for one season's operation should be cleared each year so that the remaining vegetation can furnish protection from erosion, wind, and screen the site from public view.

Any excavation or grading that will be necessary to divert surface water runoff away from the operating area should be done after the clearing is completed.

Roads connecting the landfill site to the existing road system will also need to be constructed. These roads should be suitable for all-weather use so that the collection vehicles always have access to the site. Roads on the site itself will be temporary, reflecting the changes in the operating location, but provisions must be made so that these roads are also usable in bad weather. This will usually require the presence at the site of stockpiled gravel or rock that can be used to provide a stable roadbed when necessary.

Utilities and Facilities

The utilities and facilities located at a sanitary landfill serve three main functions: the comfort and protection of the operator, the maintenance and protection of the equipment, and the protection of the environment.

For the protection of the equipment, an enclosed shed or garage is recommended. This should contain the proper tools and equipment for performing the routine preventive maintenance recommended by the equipment manufacturer. In the interest of giving the operator protection from the elements, this building may also contain provisions for a small office and could also be heated during cold weather.

In the event of an accident, or other emergency, some means of communications should be provided at the site. This could either be a telephone or a two-way radio. Toilet facilities should be provided, but usually only a pit privy or a chemical toilet will be necessary. Water will also be needed at the site for fire and dust control and for the cleaning of equipment.

Fencing

Permanent and temporary fences are needed at sanitary landfills. Permanent fencing is used around the perimeter of the site to keep unauthorized persons and animals off the site. At Yellowstone, bears are a special problem and will require a larger than average expense for fencing.

Although the best type of fence to exclude the bears will have to be determined by actual trails, it is suggested that chain-link fencing be used. This fence should be from 5 to 8 ft in height and topped with barbed wire. Special provisions will also be necessary to keep the bears from burrowing under the fence. An underground extension of the fence or an electrified wire would probably do the best job. Access to the landfill should be controlled by having gates at the entrance. The gates should be locked when the operator is not on duty.

Temporary fencing is used for traffic routing and the control of blowing litter. Snow fences located perpendicular to the prevailing winds, and downwind from the area being filled, usually prove adequate for litter control. If, however, they are not sufficient, a taller fence may have to be fabricated.

Plan of Operation

There are three basic methods of operating a sanitary landfill. These are based on the topography of the site, its geology, and the preferences of the designer and operator. All of the techniques have the objectives of sanitary landfilling in common. These are to spread the waste, to compact it into the smallest possible volume, and to cover it with earth at least daily. Each of the methods will be described below as quoted from the publication Sanitary Landfill Facts.

Area Method.

> In the area landfill, the solid wastes are placed on the land; a bulldozer or similar equipment spreads and compacts the wastes; then the wastes are covered with a layer of earth; and finally the earth cover is compacted. The area method is best suited for marshes, flat areas, or gently sloping land and is also used in quarries, ravines, valleys or where other suitable land depressions exist. Normally, the earth cover material is hauled in or obtained from adjacent areas.

Trench Method.

In a trench landfill, a trench is cut in the ground and the solid wastes are placed in the trench. The solid wastes are then spread in thin layers, compacted, and covered with earth excavated from the trench. The trench method is best suited for flat or gently sloping land where the water table is not near the ground surface. The advantage is that normally the material excavated from the trench can be used for cover with a minimum of hauling.

Ramp Method.

In the ramp or slope method (a variation of the area and trench landfills), the solid wastes are dumped on the side of an existing slope. After spreading the material in thin layers on the slope, the bulldozing equipment compacts it. The cover material, usually obtained just ahead of the working face, is spread on the ramp and compacted. As a method of landfilling, this variation is generally suited to all areas. Having the advantage of utilizing only one piece of equipment to perform all operations makes the ramp or slope method of landfill particularly applicable to smaller operations.

APPENDIX D

SANITARY LANDFILL OPERATION, YELLOWSTONE NATIONAL PARK

Equipment Selection

Because most sanitary landfills in Yellowstone National Park will be operated only 6 months of each year, it is suggested that site preparation and any necessary excavation be done with a large (15-to 20-ton) tracked dozer or loader borrowed from the Park equipment pool. This will allow the use of smaller equipment, having a lower annual cost, to operate the landfill. A front-end loader with a bucket capacity from 1 to 2 cu yd would probably be the best type of equipment to use. Either tracked or wheeled vehicles can be operated, but wheeled vehicles could also be used at other jobs during the winter months.

The special landfill accessory packages marketed by most equipment manufacturers should be investigated and purchased if possible. Sanitary landfill tires, which are puncture proo., would also be a good investment if rubber-tired equipment is used.

Operating Procedures

The following operating pocedures are quoted from Sanitary Landfill Facts, and should be followed.

Compaction.

Solid wastes should be placed at the top or base of the working face, spread in thin layers about 2 feet thick, and compacted. If a slope, or ramp, is used, better compaction will normally result if the wastes are spread and compacted from the base upwards. The degree of compaction is dependent on the character of the solid wastes, the weight and type of compacting equipment, and the number of passes the equipment makes over the material. The actual density of the landfill can be determined from operating records and data. The degree of compaction is a useful tool to determine the rate of space usage, expected life of the landfill, and the overall efficiency of the operation.

Working Face.

The size of the working face of the landfill operation is determined by the rate of unloading of the incoming vehicles. The working face should be as narrow as possible to minimize the exposed area, but not so small as to interfere with the unloading operations and the movement of landfill equipment. A minimum width of the working face should be approximately twice the width of the tractor to allow the tractor to move from side to side thus compacting the entire exposed surface.

Depth of Cells.

Cell depth is the thickness of the solid wastes layer measured perpendicular to the working slope where the equipment travels. The depth of cells is determined largely by the size of the operation, the elevation desired of the completed fill, the depth of the trench or depression to be filled, and in some cases, the amount of cover material available. Eight feet is generally recommended as a maximum single cell depth because deeper cells usually result in fills that have excessive settlement and surface cracking. However, the cell depth of presently operated sanitary landfills varies from 2 feet to 15 feet or more.

Cover. The deposited solid waste should be covered with compacted earth at the conclusion of each day's operation, or more frequently if necessary. The depth of the daily cover will be determined by the characteristics of the cover material. At least 6 in. of sandy loam are required for a good seal, therefore, coarser soils will require more than 6 in. of cover. A depth of 1 ft, or more, of compacted cover material may often be necessary in Yellowstone.

At the conclusion of sanitary landfilling operations in an area, from 2 to 3 ft of compacted earth should be applied as a final cover, to protect the waste from erosion by wind and water.

Supervision

A sanitary landfill should be under constant and competent supervision to insure a sanitary and economic operation. This supervision would most logically come from the district maintenance supervisors in Yellowstone, but they will need to be trained in the principles and practices of sanitary landfilling. The operator, or operators, of a landfill also needs to be adequately trained in its operation.

Operating Records

A system of cost accounting and record keeping for sanitary landfills is a necessary part of their operation. Such a system has been designed and is recommended for implementation at Yellowstone.